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(54) Title: PHOTONITIATORS AND OXYGEN SCAVENGING COMPOSITIONS

(57) Abstract

An oxygen scavenging composition or system is provided comprising an oxygen scavenging material, a photoinitiator, and at least one catalyst effective in catalyzing an oxygen scavenging reaction, wherein the photoinitiator comprises a benzophenone derivative containing at least two benzophenone moieties. A film, a multi-phase composition, a multi-layer composition, a multi-layer film, an article comprising the oxygen scavenging composition, a method for preparing the oxygen scavenging composition, and a method for scavenging oxygen are also provided. Non-extractable benzophenone derivative photoinitiators and methods for preparing same are also provided.

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1 PHOTOINITIATORS AND OXYGEN SCAVENGING COMPOSITIONS

2 FIELD OF THE INVENTION

3 The present invention relates to photoinitiators, methods for preparing and using
4 same, oxygen scavenging compositions, articles made from same and methods
5 of scavenging oxygen.

6 BACKGROUND OF THE INVENTION

7 The term "oxygen scavenging" means to absorb, deplete, or react with oxygen
8 from a given environment.

9 Oxygen scavenging materials have been developed partly in response to the
10 food industry's goal of having longer shelf-life for packaged food. One method
11 which is currently being employed involves the use of "active packaging" where
12 the package is modified in some way so as to control the exposure of the
13 product to oxygen. Such "active packaging" can include sachets containing
14 iron-based compositions such as AGELESS™ which scavenges oxygen within
15 the package through an oxidation reaction. However, such an arrangement is
16 not advantageous for a variety of reasons including the accidental ingestion of
17 the sachets or the oxygen scavenging material present therein.

18 Other techniques involve incorporating an oxygen scavenger into the package
19 structure itself. In such an arrangement, oxygen scavenging materials constitute
20 at least a portion of the package, and these materials remove oxygen from the
21 enclosed package volume which surrounds the product or which may leak into
22 the package, thereby, in the case of food products, inhibiting spoilage and
23 prolonging freshness.

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- 1 Oxygen scavenging materials include low molecular-weight oligomers that are
- 2 typically incorporated into polymers or can be oxidizable organic polymers. Such
- 3 oxygen scavenging materials are typically employed with a suitable catalyst, e.g.,
- 4 an organic or inorganic salt of a transition metal catalyst.

- 5 The onset of useful oxygen scavenging activity may not occur for as long as 30
- 6 days. In order to shorten the induction period and to initiate oxygen scavenging,
- 7 photoinitiators can be employed in conjunction with actinic radiation. Many of
- 8 these photoinitiators and resulting by-products are extractable and can leach into
- 9 the headspace surrounding the packaged product or even enter the product
- 10 itself. Such leaching can produce foul odors or unpleasant taste or can be
- 11 otherwise undesirable.

12

SUMMARY OF THE INVENTION

- 13 It is an object of the present invention to provide a composition effective for
- 14 oxygen scavenging under typical storage conditions.

- 15 It is another object of the present invention to provide a composition which is
- 16 effective for oxygen scavenging at low temperatures.

- 17 It is another object of the present invention to provide an oxygen scavenging
- 18 composition which produces reduced levels of extractable compounds.

- 19 It is another object of the present invention to provide an oxygen scavenging
- 20 composition which has a short initiation period upon activation.

- 21 It is another object of the present invention to provide an oxygen scavenging
- 22 composition which exhibits improved shelf life prior to activation.

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- 1 It is another object of the present invention to provide a film or a multi-layer film
- 2 capable of scavenging oxygen.

- 3 It is another object of the present invention to provide an article, package or
- 4 container suitable for oxygen scavenging.

- 5 It is another object of the present invention to provide a method for preparing an
- 6 oxygen scavenging composition.

- 7 It is another object of the present invention to provide a method for scavenging
- 8 oxygen.

- 9 It is another object of the present invention to provide novel photoinitiators which
- 10 are effective initiators for oxygen scavenging.

- 11 It is another object of the present invention to provide novel photoinitiators which
- 12 are essentially non-leachable.

- 13 It is another object of the present invention to provide methods for preparing
- 14 novel photoinitiators.

- 15 According to the present invention, an oxygen scavenging composition or system
- 16 is provided comprising an oxygen scavenging material, a photoinitiator, and at
- 17 least one catalyst effective in catalyzing the oxygen scavenging reaction. The
- 18 photoinitiator comprises a benzophenone derivative containing at least two
- 19 benzophenone moieties. A film, a multi-phase composition, a multi-layer
- 20 composition, a multi-layer film, an article comprising the oxygen scavenging
- 21 composition, as well as a method for preparing the oxygen scavenging
- 22 compositions, and a method for scavenging oxygen are also provided.

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- 1 According to other aspects of the present invention, non-extractable
- 2 photoinitiators and methods for preparing same are provided.

3 BRIEF DESCRIPTION OF THE DRAWINGS

- 4 Figures 1, 2 and 3 are a graphic representation of the effectiveness of various
- 5 photoinitiators.

6 DETAILED DESCRIPTION OF THE INVENTION

7 It has been found that benzophenone derivatives containing at least two
8 benzophenone moieties act as effective photoinitiators to initiate oxygen
9 scavenging activity in oxygen scavenging compositions and to provide a
10 composition having a very low degree of extraction of the photoinitiators which
11 may contaminate a packaged product. By benzophenone moiety is meant a
12 substituted or unsubstituted benzophenone group. Suitable substituents are any
13 substituent which does not interfere with the objects of the invention and include
14 alkyl, aryl, alkoxy, phenoxy, and alicyclic groups containing from 1 to 24 carbon
15 atoms or halides.

16 These derivatives are substantially non-extractable by most organic solvents at
17 room temperature. By substantially non-extractable is meant that less than
18 about 500 ppb photoinitiator are extracted through a 0.5 mil polyethylene film in
19 ten days at room temperature from an oxygen scavenging composition
20 containing 1000 ppm by weight photoinitiator when exposed to 10 g fatty food
21 simulant per square inch of 1 mil film, preferably 250 ppb photoinitiator or less
22 are extracted, more preferably 100 ppb photoinitiator or less are extracted, and
23 most preferably 50 ppb photoinitiator or less are extracted.

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1 Such benzophenone derivatives include dimers, trimers, tetramers, and
2 oligomers of benzophenone-type photoinitiators derived from benzophenone and
3 substituted benzophenones, as fully described herein below.

4 The substantially non-extractable photoinitiators are represented by the following
5 formula:

6 $X_m(Y)_n$

7 Wherein each X is a bridging group selected from the group consisting of sulfur;
8 oxygen; carbonyl; $-SiR_2-$, wherein each R is individually selected and is an alkyl
9 group containing from 1 to 12 carbon atoms, an aryl group containing 6 to
10 12 carbon atoms, or an alkoxy group containing from 1 to 12 carbon atoms;
11 $-NR'$, wherein R' is an alkyl group containing 1 to 12 carbon atoms, aryl group
12 containing 6 to 12 carbon atoms, or hydrogen; and an organic group containing
13 from 1 to 50 carbon atoms, preferably from 1 to 40 carbon atoms. X can be a
14 divalent group or can be a polyvalent group with 3 or more benzophenone
15 moieties attached. Wherein m is 0 to 11.

16 The organic bridging group, when present, can be linear, branched, cyclic
17 including fused or separate cyclic groups or an arylene group which can be fused
18 or non-fused polyaryl groups. The organic bridging group can contain one or
19 more heteroatoms such as oxygen, nitrogen, phosphorous, silicon or sulfur or
20 combinations thereof. Oxygen can be present as an ether, ketone, ester, or
21 alcohol.

22 Wherein each Y is a substituted or unsubstituted benzophenone group. Wherein
23 each substituent, R", when present, is individually selected from any substituent
24 which does not substantially interfere with the objects of the invention and

- 1 include alkyl, aryl, alkoxy, phenoxy, or alicyclic groups containing from 1 to
- 2 24 carbon atoms, or halides. Each benzophenone moiety can have up to
- 3 9 substituents. Wherein n is 2-12.
- 4 Preferably, the combined molecular weight of the X and R" groups is at least
- 5 about 30 g/mole. Appropriate choice of substituents can render the photoinitiator
- 6 more compatible with the oxygen scavenging composition. Such substituents
- 7 include alkyl and alkoxy for example.
- 8 Preferably, the oxygen scavenging composition consumes half of the available
- 9 oxygen in a container containing 1 percent oxygen in less than 4 days at 25°C.
- 10 More preferably, the oxygen scavenging composition consumes half of the
- 11 available oxygen in a container containing 1 percent oxygen in less than 4 days
- 12 at 4°C.
- 13 The photoinitiators include multiplets of ultraviolet (UV) initiators linked by cross
- 14 conjugation so as to retain the UV absorption characteristics with enhanced UV
- 15 absorptivity, i.e., higher extinction coefficient. The linkages within the dimers,
- 16 trimers, tetramers, and oligomers can be flexible or rigid. The rigid type are
- 17 preferred for lower extractability. However, a certain degree of flexibility is
- 18 required to facilitate the melt blending to allow a molecular level distribution in
- 19 the polymer films.
- 20 Typically, these compounds have a strong UV absorption at about 200-400 nm.
- 21 Generally, the molecular weight will be greater than about 360 g/mole, preferably
- 22 in the range of from about 360 g/mole to about 5000 g/mole, more preferably in
- 23 the range of from 390 g/mole to 4000 g/mole.

- 1 The photoinitiators are substantially non-extractable by most organic solvents
- 2 when incorporated into oxygen scavenging compositions. They provide efficient
- 3 light absorption to trigger a photochemical induced oxidation. The photoinitiators
- 4 are stable and do not fragment into extractable by-products. The photoinitiators
- 5 are also large enough or rigid enough to be immobile and therefore cannot be
- 6 leached into the packaged food or product. The photoinitiators do not sublime
- 7 under normal processing and handling conditions. This assures an extended
- 8 shelf life for the preactivated composition and a safe packaging material
- 9 according to U.S. Food and Drug Administration standards.

- 10 Examples of non-extractable photoinitiators include dibenzoyl biphenyl,
- 11 substituted dibenzoyl biphenyl, benzoylated terphenyl, substituted benzoylated
- 12 terphenyl, tribenzoyl triphenylbenzene, substituted tribenzoyl triphenylbenzene,
- 13 benzoylated styrene oligomer, and substituted benzoylated styrene oligomer.
- 14 Benzoylated styrene oligomer is a mixture of compounds containing from 2 to
- 15 12 repeating styrenic groups comprising dibenzoylated 1,1-diphenyl ethane,
- 16 di-benzoylated 1,3 diphenyl propane, di-benzoylated 1-phenyl naphthalene,
- 17 dibenzoylated styrene dimer, dibenzoylated styrene trimer and tribenzoylated
- 18 styrene trimer.

- 19 Suitable substituents for the above compounds include any substituent which
- 20 does not interfere substantially with the objects of the invention and include alkyl,
- 21 aryl, alkoxy, phenoxy, and alicyclic groups containing from 1 to 24 carbon atoms
- 22 or halides.

- 23 Typical examples of suitable alkyl groups include methyl, ethyl, propyl, isopropyl,
- 24 butyl, t-butyl, pentyl, dodecyl, hexadecyl, octadecyl and the like. Specific
- 25 examples of alkoxy groups include methoxy, ethoxy, propoxy, butoxy,

- 1 dodecyloxy and the like. Examples of alicyclic groups include cyclopentyl,
- 2 cyclohexyl, cycloheptyl and the like. The hydrocarbon substituents can be
- 3 saturated or can contain ethylenic unsaturation.

- 4 Examples of specific photoinitiators include 4,4'-bis(4,4'-dimethyldibenzoyl)
- 5 biphenyl; 4,4'-bis(4,4'-diethyldibenzoyl) biphenyl; 4,4'-bis(2,2'-dimethyldibenzoyl)
- 6 biphenyl; 4,4'-bis(2,2'-dimethoxydibenzoyl) biphenyl; 4,4'-bis(4-
- 7 dodecyldibenzoyl) biphenyl; 4,4'-bis(2,2'-diacetyldibenzoyl) biphenyl;
- 8 4,4-bis(4,4'-dimethyldibenzoyl) diphenyl ether; 4,4'-bis(4,4'-diethyldibenzoyl)
- 9 diphenyl ether; 4,4'-bis(2,2-dimethyldibenzoyl) diphenyl ether;
- 10 4,4'-bis(2,2'-dimethoxydibenzoyl) diphenyl ether; 4,4'-bis(4-dodecyldibenzoyl)
- 11 diphenyl ether; 4,4'-bis(2,2'-diacetyldibenzoyl)diphenyl ether;
- 12 4,4'-bis(4,4'-dimethyldibenzoyl)diphenyl sulfide; 4,4'-bis-
- 13 diethyldibenzoyl)diphenyl sulfide; 4,4'-bis(2,2'-dimethyldibenzoyl)diphenyl sulfide;
- 14 4,4'-bis(2,2'-dimethoxydibenzoyl) diphenyl sulfide; 4,4'-bis(4-dodecyldibenzoyl)
- 15 diphenyl sulfide; 4,4'-bis(2,2'-diacetyldibenzoyl) diphenyl sulfide;
- 16 4,4'-bis(4,4'-dimethyldibenzoyl) diphenyl amine; 4,4'-bis(4,4'-diethyldibenzoyl)
- 17 diphenyl amine; 4,4-bis(2,2'-dimethyldibenzoyl) diphenyl amine;
- 18 4,4'-bis(2,2'-dimethoxydibenzoyl) diphenyl amine; 4,4'-bis(4-dodecyldibenzoyl)
- 19 diphenyl amine; 4,4'-bis(2,2'-diacetyldibenzoyl) diphenyl amine;
- 20 4,4'-bis(4,4'-dimethyldibenzoyl) diphenyl dimethyl silane;
- 21 4,4'-bis(4,4'-diethyldibenzoyl) diphenyl dimethyl silane; 4,4'-bis(2,2'-
- 22 dimethyldibenzoyl) diphenyl dimethylsilane; 4,4'-bis(2,2'-dimethoxydibenzoyl)
- 23 diphenyl dimethyl silane; 4,4'-bis(4-dodecyldibenzoyl) diphenyl dimethyl silane;
- 24 4,4'-bis(2,2'-diacetyldibenzoyl) diphenyl dimethyl silane;
- 25 4,4'-bis(4,4'-dimethyldibenzoyl) benzophenone; 4,4'-bis(4,4'-diethyldibenzoyl)
- 26 benzophenone; 4,4'-bis(4,4'-dipropylidibenzoyl) benzophenone;
- 27 4,4'-bis(2,2'-dimethoxydibenzoyl) benzophenone; 4,4'-bis(4-dodecyldibenzoyl)

- 1 benzophenone; 4,4-bis(2,2'-diacetylbenzoyl) benzophenone;
- 2 4,4'-bis(4,4'-dimethylbenzoyl) diphenyl methane; 4,4'-bis(4,4'-diethyldibenzoyl)
- 3 diphenyl methane; 4,4'-bis(4,4'-dipropyldibenzoyl) diphenyl methane;
- 4 4,4'-bis(2,2'-dimethoxydibenzoyl) diphenyl methane; 4,4-bis(4-dodecylbenzoyl)
- 5 diphenyl methane; 4,4'-bis(2,2'-diacetylbenzoyl) diphenyl methane;
- 6 4,4'-dibenzoyl-1,4-diphenoxyl butane; 4,4'-dibenzoyl-1,2-diphenoxyl ethane;
- 7 4,4'-bis(4,4'-dimethylbenzoyl)-1,4-diphenoxyl butane; 4,4'-dibenzoyl-1,12-
- 8 diphenoxyl dodecane; tritoluoyl triphenyl benzene, tri(para-methoxybenzoyl)
- 9 triphenyl benzene, dibenzoyl meta-terphenyl, ditoluoyl meta-terphenyl, ditoluoyl
- 10 para-terphenyl, diethylbenzoyl meta-terphenyl, dipropyldibenzoyl
- 11 ortho-terphenyl, dibutyldibenzoyl para-terphenyl, dipentyldibenzoyl
- 12 meta-terphenyl, dihexyldibenzoyl ortho-terphenyl, diheptyldibenzoyl
- 13 para-terphenyl, dioctyldibenzoyl meta-terphenyl, dioctadecyl dibenzoyl
- 14 ortho-terphenyl, and the like.

- 15 The photoinitiator is present in an amount sufficient to decrease the induction
- 16 period after UV triggering. The amount of photoinitiator employed can vary
- 17 broadly depending on the oxygen scavenging material employed, the
- 18 wavelength, time of exposure and intensity of the radiation used, the type of
- 19 photoinitiator, time of exposure and the amount of antioxidants employed, if any.

- 20 Generally, the photoinitiator will be present in an amount in the range of from
- 21 about 0.001 weight percent to about 10 weight percent based on the total weight
- 22 of the oxygen scavenging composition, preferably from 0.005 weight percent to
- 23 5 weight percent, and more preferably from 0.01 weight percent to 1 weight
- 24 percent.

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- 1 An effective photoinitiator is one which provides the oxygen scavenging
- 2 composition an induction period of one day or less. The photoinitiator should be
- 3 effective at 25°C and preferably also effective at 4°C.
- 4 The photoinitiator can be introduced into the oxygen scavenging composition by
- 5 any method known in the art such as coating techniques and extrusion
- 6 compounding (including masterbatching). The photoinitiators can be introduced
- 7 into polymers under conventional melt processing conditions to provide good
- 8 mixing without plate-out on the machine.
- 9 The photoinitiator tribenzoyl triphenylbenzene can be prepared by reacting a
- 10 benzoyl halide, such as benzoyl chloride, and a triphenylbenzene. The benzoyl
- 11 halide and triphenylbenzene can contain additional substituents. Suitable
- 12 substituents comprise any substituent which does not interfere substantially with
- 13 the reaction and include alkyl, aryl, alkoxy, phenoxy, and alicyclic groups
- 14 containing from 1 to 24 carbon atoms or halides.
- 15 Preferably, an aluminum- or boron-containing catalyst such as aluminum
- 16 trichloride or boron trifluoride is employed.
- 17 Conditions for reacting the benzoyl chloride and triphenylbenzene can vary
- 18 broadly. Generally, the reaction temperature is in the range of from about -20°C
- 19 to about 150°C, preferably from about -10°C to about 120°C. The pressure is
- 20 not critical and ambient pressure is suitable. Typically, the reaction would be
- 21 conducted in a suitable diluent such as nitrobenzene, chlorobenzene,
- 22 dichlorobenzene, dichloromethane, dichloroethane, trichloroethane, or carbon
- 23 disulfide.

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- 1 The photoinitiator benzoylated styrene oligomer can be prepared by reacting
- 2 styrene trimers with a benzoyl halide, such as benzoyl chloride. Styrene trimers
- 3 can be distilled from a polystyrene by-products stream. The benzoyl halide and
- 4 styrene trimers can contain additional substituents. Suitable substituents
- 5 comprise any substituent which does not interfere substantially with the reaction
- 6 and include alkyl, aryl, alkoxy, phenoxy, and alicyclic groups containing from 1 to
- 7 24 carbon atoms or halides.

- 8 Preferably, an aluminum- or boron-containing catalyst such as aluminum
- 9 trichloride or boron trifluoride is employed.

- 10 The reaction produces a mixture of products including the major components
- 11 di-benzoylated styrene trimer, tri-benzoylated styrene pentamer,
- 12 tetra-benzoylated styrene pentamer, di-benzoylated styrene dimer, and minor
- 13 components including benzoylated 1-phenyl naphthalene, benzoylated styrene
- 14 dimer, di-benzoylated 1,3 di-phenyl propane, di-benzoylated 1-phenyl
- 15 naphthalene, benzoylated 1,1-di-phenyl ethane, and benzoylated ethyl-benzene.

- 16 Conditions for reacting the benzoyl halide and styrene trimers can vary broadly.
- 17 Generally, the reaction temperature is in the range of from about 0°C to about
- 18 100°C. The pressure is not critical and ambient pressure is suitable.

- 19 The photoinitiator benzoylated terphenyl can be prepared by reacting a terphenyl
- 20 and a benzoyl halide, such as benzoyl chloride. The terphenyl can be para-,
- 21 meta- or ortho-terphenyl. The terphenyl and benzoyl halide can contain
- 22 additional substituents. Suitable substituents comprise any substituent which
- 23 does not interfere substantially with the reaction and include alkyl, aryl, alkoxy,
- 24 phenoxy, and alicyclic groups containing from 1 to 24 carbon atoms or halides.

- 1 Generally, a catalyst such as aluminum chloride is employed. The reaction is
- 2 generally conducted in a suitable solvent such as nitrobenzene, chlorobenzene,
- 3 dichlorobenzene, dichloromethane, dichloroethane, trichloroethane, or carbon
- 4 disulfide.
- 5 Conditions for reacting the terphenyl and benzoyl halide can vary broadly.
- 6 Generally, the reaction temperature is in the range of from about 0°C to about
- 7 100°C. The product comprising di-benzoylated terphenyl can be isolated by
- 8 recrystallization from toluene.
- 9 The oxygen scavenging material can be any material known in the art to
- 10 scavenge oxygen, providing that the material does not compete strongly for UV
- 11 absorption in the critical region where the photoinitiator absorbs light. The
- 12 oxygen scavenging material can be any organic compound or polymer which
- 13 contains an oxidizable site. Preferred compounds include ethylenically
- 14 unsaturated compounds and those containing benzylic, allylic and/or tertiary
- 15 hydrogen. Examples of such organic compounds include squalene, dehydrated
- 16 castor oil, polybutene or polypropylene.
- 17 Substituted oxidizable polymers include polymers and copolymers containing
- 18 esters, carboxylic acids, aldehydes, ethers, ketones, alcohols, peroxides, and/or
- 19 hydroperoxides. Preferably, the oxidizable polymers contain two or more
- 20 ethylenically unsaturated sites per molecule, more preferably three or more
- 21 ethylenically unsaturated sites per molecule.
- 22 Other oxidizable compounds suitable as oxygen scavenging materials include
- 23 those described in U.S. Pat. Nos. 5,211,875 and 5,346,644 to Speer et al., which
- 24 are hereby incorporated by reference in their entirety. Examples of oxidizable

1 compounds include polybutadiene, polyisoprene, styrene-butadiene block
2 copolymers, polyterpenes, poly(meta-xyleneadipamide) (also known as MXD6),
3 polymers of fatty acids such as oleic, ricinoleic, dehydrated ricinoleic, and linoleic
4 acids and esters of such acids, acrylates which can be prepared by
5 transesterification of poly(ethylene-methyl acrylate) such as poly(ethylene-methyl
6 acrylate-benzyl acrylate), poly(ethylene-methyl acrylate-tetrahydrofuryl
7 acrylate), poly(ethylene-methyl acrylate-nopol acrylate) and mixtures thereof.
8 Such transesterification processes are disclosed in U.S. Serial No. 08/475,918
9 filed June 7, 1995, the disclosure of which is hereby incorporated by reference.
10 Butadiene polymers and copolymers, such as styrene-butadiene-styrene block
11 copolymer, are preferred for low temperature applications requiring
12 transparency.

13 The polyterpenes such as poly(alpha-pinene), poly(dipentene),
14 poly(beta-pinene), and poly(limonene)are especially effective oxygen scavenger
15 materials and produce reduced amounts of migratory carboxylic acids,
16 aldehydes and alkenes which can produce objectionable odors and tastes.

17 The oxygen scavenging material can be introduced into the oxygen scavenging
18 system by a variety of techniques. The oxygen scavenging material can be
19 formed into films which can be a separate layer in a multi-layer structure, coated
20 or laminated onto a material such as aluminum foil or paper, formed into bottles
21 or other rigid containers, or even incorporated into a material such as paper, for
22 example, in flexible and rigid packaging. The oxygen scavenging material can
23 also be in a localized area on a layer; for example, it may be in a patch that is
24 laminated to another layer. The oxygen scavenging composition can contain a
25 mixture of two or more oxidizable organic compounds.

- 1 The oxygen scavenging material is generally present in the oxygen scavenging
2 composition in an amount sufficient to scavenge at least 0.1 cc O₂/gram of
3 oxygen scavenging composition/day at 25°C. Preferably, it is capable of
4 scavenging at least about 0.5 cc O₂, and more preferably at least about 1 cc
5 O₂/gram of oxygen scavenging composition/day at 25°C. For many applications,
6 such as food and beverage storage, it is desirable to select an oxygen
7 scavenging material which will effectively scavenge oxygen as indicated at a
8 temperature of 4°C.

- 9 The amount of oxygen scavenging material employed in the oxygen scavenging
10 composition can vary broadly depending on the desired characteristics of the
11 final product. Generally, the oxygen scavenging material is present in an amount
12 in the range of from about 1 weight percent to about 99 weight percent based on
13 the total oxygen scavenging composition, preferably from about 5 weight percent
14 to about 95 weight percent, and more preferably from 10 weight percent to
15 90 weight percent.

- 16 The catalyst can be any catalyst known in the art which is effective in initiating
17 the oxygen scavenging reaction. Typical catalysts include transition metal salts.
18 Suitable catalysts are disclosed in U.S. Pat. Nos. 5,211,875 and 5,346,644 to
19 Speer et al., the disclosures of which were previously incorporated by reference
20 in their entirety. Suitable transition metal salts are those which contain
21 manganese, iron, cobalt, nickel, copper, rhodium, and ruthenium, preferably iron,
22 nickel copper, manganese or cobalt.

- 23 Cobalt compounds containing organic or inorganic anions are preferred.
24 Suitable anions include chloride, acetate, stearate, caprylate, palmitate,
25 2-ethylhexanoate, citrate, glycolate, benzoate, neodecanoate, naphthenate,

1 oleate, and linoleate. Organic anions are preferred and cobalt oleate, cobalt
2 linoleate, cobalt neodecanoate, cobalt stearate and cobalt caprylate are
3 especially preferred. It has been found that a composition comprising the
4 combination of cobalt stearate and benzoylated styrene oligomer is especially
5 effective at scavenging oxygen at low temperature and oxygen levels, e.g., 1%
6 oxygen levels at 4°C.

7 The catalyst is present in an amount sufficient to catalyze the oxygen
8 scavenging reaction. Generally, the catalyst will be present in an amount in the
9 range of from about 10 parts per million by weight (ppm) to about 10,000 ppm by
10 weight transition metal ion based on the total weight of the oxygen scavenging
11 composition, preferably from 10 ppm to 5,000 ppm transition metal ion.

12 The catalyst can be introduced in any manner which does not react with and/or
13 deactivate the catalyst. For example, the catalyst can be applied onto the
14 oxygen scavenging material by any suitable means, e.g., coating techniques
15 such as spray coating, extrusion compounding or lamination. Further, the
16 catalyst may be included as part of a compounded master batch using a suitable
17 carrier resin.

18 The oxygen scavenging composition can be activated by methods known in the
19 art such as by actinic radiation, i.e., ultraviolet or visible light having a wave
20 length in the range of from about 200 nm to about 750 nm, electron beam, or
21 thermal triggering. Such methods are described in U.S. Pat. No. 5,211,875, the
22 disclosure of which is hereby incorporated by reference. The composition is
23 typically activated with at least 0.1 J/cm², preferably in the range of from
24 0.5 J/cm² to 200 J/cm² of UV radiation in the range of from 200 nm to 400 nm,
25 preferably in the range of from 0.5 J/cm² to 100 J/cm², and more preferably in the

- 1 range of from 0.5 J/cm² to 20 J/cm². The composition can also be activated with
- 2 an electron beam at a dosage of about 0.2 to 20 megarads, preferably about 1 to
- 3 10 megarads. Other sources of radiation include ionizing radiation, such as
- 4 gamma, x-rays or corona discharge. The radiation is preferably conducted in the
- 5 presence of oxygen.
- 6 The duration of exposure depends on several factors including the amount and
- 7 type of photoinitiator present, thickness of the layers to be exposed, amount of
- 8 any antioxidant present, and the wavelength and intensity of the radiation
- 9 source. The activation is conducted prior to using the layer or article. Exposure
- 10 to a flat layer or article provides the most uniform radiation.
- 11 For many applications, the oxygen scavenging composition can contain a diluent
- 12 polymer to provide desired characteristics. Suitable diluent polymers include
- 13 polyethylene, polypropylene, poly(vinyl chloride), and ethylene copolymers such
- 14 as ethylene-vinyl acetate, ethylene-alkyl acrylates, ethylene-acrylic acid,
- 15 ethylene-acrylic acid ionomers, and mixtures thereof.
- 16 In another aspect of the invention, the oxygen scavenging composition
- 17 comprises a first phase comprising the oxygen scavenging material and a
- 18 second phase comprising the catalyst. Such compositions are disclosed in U.S.
- 19 Serial No. 08/388,815 filed February 15, 1995, the disclosure of which is
- 20 incorporated herein by reference. The first phase is essentially devoid of
- 21 catalyst. The second phase is in sufficiently close proximity to the first phase to
- 22 catalyze the oxygen scavenging reaction. When the oxygen scavenging material
- 23 and the catalyst are in separate phases, processing difficulties, such as
- 24 deactivation of the catalyst or shortened shelf-life, are avoided.

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1 In another aspect of the invention, the catalyst is incorporated into a polymeric
2 material to form at least one catalyst-containing layer. This layer is then brought
3 into contact with the oxygen scavenging material. The particular polymeric
4 material used is not critical as long as it does not deactivate the catalyst.

5 In another aspect of the invention, the oxygen scavenging composition or system
6 can include a polymeric selective barrier layer. Such compositions are disclosed
7 in U.S. Serial No. 08/304,303 filed September 12, 1994, the disclosure of which
8 is incorporated herein by reference. The selective barrier layer functions as a
9 selective barrier to certain oxidation by-products, but does allow the transmission
10 of oxygen. Preferably, the layer prevents at least half of the number and/or
11 amount of oxidation by-products having a boiling point of at least 40°C from
12 passing through the polymeric selective barrier layer. Preferably, the selective
13 barrier is located between the packaged item and the oxygen scavenging
14 material.

15 The oxygen scavenging composition can also contain an oxygen barrier layer
16 located on the outside of the scavenging layers to prevent the entry of oxygen
17 into the sealed package. Typical oxygen barriers include poly(ethylene
18 vinylalcohol), polyvinylalcohol, polyacrylonitrile, poly(vinyl chloride),
19 poly(vinylidene dichloride), poly(ethylene terephthalate), silica coatings and
20 polyamides such as Nylon 6, and Nylon 6,6 and MXD6. Copolymers of certain
21 materials described above and metal foil layers can also be employed.

22 Additional layers such as adhesive layers or heat seal layers may also be
23 employed. Adhesive layers include anhydride functionalized polyolefins.

1 The oxygen scavenging composition can include additives, stabilizers,
2 plasticizers, fillers, pigments, dyestuffs, processing aids, anti-blocks, plasticizers,
3 fire retardants, antifog agents, etc., which do not interfere with the oxygen
4 scavenging function. The composition can also include antioxidants which inhibit
5 the formation of free radicals and therefore improve storage of the oxygen
6 scavenging composition prior to its use in oxygen scavenging applications. The
7 presence of such antioxidants inhibits the initiation of the oxygen scavenging
8 reaction until the photoinitiator is activated by radiation. Therefore, the amount
9 employed will depend on the desired storage life of the composition, the
10 photoinitiator, and the activation method employed.

11 The present oxygen scavenging compositions or systems are useful in improving
12 the shelf-life of packaged oxygen-sensitive products such as food,
13 pharmaceuticals, cosmetics, chemicals, electronic devices, and health and
14 beauty products. The system can be used in rigid containers, flexible bags, or
15 combinations of both. The system can also be used in moldings, coatings,
16 strip/ribbon, patches, bottle cap inserts, and molded or thermoformed shapes,
17 such as bottles and trays. In all of these applications, the oxygen scavenging
18 composition effectively scavenges oxygen, whether it comes from the headspace
19 of the packaging, is entrained in the food or product, or originates from outside
20 the package.

21 Oxygen scavenging layers and articles are preferably prepared by melt-blending
22 techniques. However, other methods such as the use of a solvent followed by
23 evaporation may also be employed. When the blended composition is used to
24 make film layers or articles, coextrusion, solvent casting, injection molding,
25 stretch blow molding, orientation, thermoforming, extrusion coating, coating and

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1 curing, lamination, extrusion lamination or combinations thereof would typically
2 follow the blending.

3 The present invention will now be described further in terms of certain examples
4 which are solely illustrative in nature and should in no way limit the scope of the
5 present invention.

EXAMPLES

Example 1

8 Tribenzoyl Triphenylbenzene

The photoinitiator tribenzoyl triphenylbenzene was prepared by placing 300 mL nitrobenzene, 152 g (1.06 mole) benzoyl chloride, and 100 g (0.33 mole) triphenylbenzene into a 2 L 4-necked flask. The mixture was warmed to about 60°C and 348 g (2.52 moles) aluminum trichloride was slowly added over a period of about 1 hour. The temperature rose to about 80°C and was maintained for about 4 hours. The mixture was cooled to about 40°C. The reaction mixture was poured into a solution of 340 g of HCl and 2 L water while stirring vigorously. The mixture was allowed to stand overnight and the water was decanted. The remaining mixture was filtered, washed with distilled water, and the wet cake was transferred into a 2 L 3-necked flask equipped with a mechanical stirrer. To the flask was added 900 mL distilled water. The reaction mixture was vacuum distilled until all nitrobenzene was removed. The reaction mixture was cooled, filtered and washed with water. The solid tribenzoyl triphenylbenzene was boiled in methanol, cooled and filtered. The solid was dissolved in 350 mL hot chloroform with activated carbon black and was boiled for 10 minutes and then filtered. The thus-prepared tribenzoyl triphenylbenzene solid was recrystallized

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1 again with hot chloroform, washed with methanol, and dried. The product was
2 characterized by NMR, UV, IR and exhibited a melting point of 195°C. The
3 molecular weight determined by mass spectrometry was 618.

4

Benzoylated Styrene Oligomer

5 A mixture of styrene trimers was distilled from a polystyrene by-products stream.
6 Then 95 g (0.3 mol) of this trimer mixture was slowly added to a solution of 218 g
7 (2 moles) of benzoyl chloride and 134 g (1 mole) of AlCl₃. After stirring
8 overnight, the mixture was poured into a solution of 250 g NaOH in 700 ml of
9 water and 100 g of ice with constant stirring. Then 2000 ml of toluene was
10 added to the mixture which was stirred an additional 2 hours. The mixture was
11 filtered to remove Al(OH)₃ and the organic layer was washed twice with 500 ml
12 portions of saturated NaCl solution followed by two additional washes with
13 1000 ml of distilled water. The organic layer was dried overnight with MgSO₄.
14 After filtering off the MgSO₄, the solvent was removed under vacuum on a rotary
15 evaporator to yield 112 g of a dark brown, viscous liquid. Analysis of the product
16 showed it comprised a mixture of mono-, di-, and tri-benzoylated compounds.
17 The mixture comprises the non-extractable photoinitiators dibenzoylated
18 1,1-diphenyl ethane, di-benzoylated 1,3 diphenyl propane, di-benzoylated
19 1-phenyl naphthalene, dibenzoylated styrene dimer, and dibenzoylated styrene
20 trimer.

21

Ditoluoyl Biphenyl

22 The photoinitiator ditoluoyl biphenyl was prepared by placing 300 mL
23 nitrobenzene, 38.6 g (0.25 mole) biphenyl, and then 77.3 g (0.5 mole) p-toluoyl
24 chloride into a 1 liter 4-necked flask equipped with a water condenser. The
25 reaction mixture was cooled to -2°C. While stirring, 66.7 g (0.5 mole) aluminum

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1 trichloride was added slowly over a period of about 20 minutes. During the
2 reaction, the temperature increased to 14°C. The color changed from light
3 yellow to reddish and then to dark green. The ice bath was removed and the
4 reaction mixture was stirred at room temperature for 1 hour. The water bath
5 temperature was increased to 67°C and stirred for 20 hours. The temperature
6 was increased to about 90°C for 3 hours. The reaction mixture was poured with
7 vigorous stirring into 1.2 L of 8% HCl solution. The mixture was stirred for
8 1/2 hour, then 2 L chloroform was added. The organic layer was separated and
9 washed with 2 x 1 L sodium bicarbonate solution followed by 2 x 1 L water. The
10 organic layer was dried by magnesium sulfate. The solvent was removed by
11 vacuum and the remaining solid was washed with 2 x 200 mL water. The
12 thus-produced ditoluoyl biphenyl was dissolved in 1 L chloroform and 800 mL
13 toluene and treated with carbon black. The mixture was heated for 10 minutes
14 and filtered hot. The thus-produced ditoluoyl biphenyl crystallized out upon
15 cooling and was dried under vacuum overnight.

Dibenzoyl Biphenyl

17 The photoinitiator dibenzoyl biphenyl was prepared by placing 200 mL
18 nitrobenzene, 38.5 g (0.25 mole) biphenyl, and 140.6 g (1.00 mole) benzoyl
19 chloride into a 1 liter 3-necked flask equipped with a water condenser. While
20 stirring, 160 g (1.2 mole) aluminum trichloride was added slowly over a period of
21 about 30 minutes. During the reaction, the temperature increased from 30°C to
22 55°C. The color changed from yellowish to light brown, then reddish. The flask
23 was kept in a water bath at a temperature of 55°C to 60°C for 3 hours while
24 stirring. The reaction mixture was then cooled to 35°C. The reaction mixture
25 was poured into 1.2 L of 8% HCl solution with vigorous stirring. The organic
26 layer was separated and poured into a blender and 500 mL n-hexane was
27 added. The mixture was vigorously stirred for 5 minutes and then filtered. The

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- 1 solid was washed with n-hexane. The thus-produced dibenzoyl biphenyl was
- 2 dried and recrystallized twice in chloroform.

3

Film Preparation

- 4 Oxidizable resin, carrier resin, catalyst and the photoinitiator to be evaluated
- 5 were compounded in a twin screw extruder (Haake Rheocord TW-100 or Werner
- 6 & Pfleiderer ZSK-30) at about 170°C. The carrier resin was polyethylene,
- 7 PE1017, from Chevron and the oxidizable resin was styrene-butadiene-styrene
- 8 copolymer, Vector 8508D from Dexco. The catalyst was 1000 ppm by weight
- 9 cobalt in the form of cobalt oleate based on the total weight of the film. The
- 10 indicated photoinitiator was present in the amount of 1000 ppm based on the
- 11 total weight of the film. The compounded polymer containing the catalyst and
- 12 40% Vector and 60% PE1017 was pelletized. A Randcastle cast film multi-layer
- 13 micro extruder was employed to create three-layer films in an "ABA" structure in
- 14 which "A", the outer layers, were 0.5 mil Dowlex 3010 polyethylene and "B", the
- 15 inner layer, was 1.0 mil of the compounded polymer. Total film thickness was
- 16 2.0 mils.

17

Head Space Oxygen Absorption

- 18 Samples of 5 x 20 cm size 3 layer films made above with an average weight of
- 19 0.42 gram were irradiated under a 254 nm UV lamp for a fixed period of time
- 20 (e.g., 1 minute, approximately 600 mJ/cm² of light energy measured at 254 nm).
- 21 The film was immediately sealed in an aluminum foil bag which was evacuated
- 22 and filled with 300 mL 1% oxygen. The oxygen content was monitored by
- 23 Mocon oxygen headspace analyzer for a week and oxygen level recorded.
- 24 The results are graphically represented in Figures 1 and 2.

1

Extraction Test

2 FDA recommendations for conducting migration (extraction) studies are found in
3 "Recommendations for Chemistry Data for Indirect Food Additive Petitions",
4 Food & Drug Administration (Chemistry Review Branch, Office of Premarket
5 Approval, Center for Food Safety & Applied Nutrition), Washington, D.C. 20204,
6 June 21, 1995.

7 Extraction tests were conducted using three methods. In the first extraction
8 method, Method A, a 5 by 20 cm (15.5 sq. in.) piece of the film was irradiated (or
9 not) and placed in a 20 ml headspace vial with 14 grams of ethanol. The vials
10 were sealed with a crimped septum cap. The extraction period was 10 days at
11 room temperature. The vials were opened and the film removed. The extracts
12 were then stored at room temperature in the dark before testing.

13 In the second extraction method, Method B, a 2-inch diameter film sample was
14 activated with 800 mJ/cm² UV, then placed in a gas tight cylindrical aluminum
15 extraction cell. The extraction cell was flushed with gas containing 1% oxygen.
16 A slight positive pressure was produced. Oxygen scavenging was allowed to
17 occur within the cell at room temperature for 10 days. The oxygen scavenging
18 results are graphically represented in Figures 1 and 2. Then 12.5 grams 95%
19 ethanol was added to each cell through a septum. Residual volume of gas was
20 set at 7-8 ml. The cell was inverted to allow contact of ethanol with the oxidized
21 film and then placed in nitrogen cabinet at room temperature for 11 days. The
22 extract was removed from the cells using a syringe needle in one septum and
23 pressurizing the cell with nitrogen using a second needle in a second septum.
24 The extracts were held in the dark at room temperature before testing.

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- 1 In the third extraction method, Method C, film was extracted with Miglyol 812
- 2 (derived from coconut oil) in an extraction cell as described in Method B at a ratio
- 3 of 10 g solvent/in². Samples were extracted at room temperature for 10 days.
- 4 The extracts from all methods were then analyzed for photoinitiator extractives
- 5 using gas chromatography (GC-FID) or liquid chromatography (HPLC) methods
- 6 which were calibrated using standard solutions of each photoinitiator. Those
- 7 photoinitiators having low enough boiling points to permit them to pass through a
- 8 GC column (DB-1, 0.5 mm ID, 60/5/10/300/60°C temperature program) were
- 9 analyzed using gas chromatography. Anthrone, xanthone, 4-benzoyl biphenyl
- 10 and dibenzoyl biphenyl were determined by gas chromatography. The remaining
- 11 compounds could not be analyzed using gas chromatography methods because
- 12 of their high boiling points. Liquid chromatography methods were used for these
- 13 compounds.
- 14 In Table 1 below:
- 15 ANTH is anthrone.
- 16 XAN is xanthone.
- 17 BBP is 4-benzoyl biphenyl.
- 18 BBDE is 4,4'-bis(benzoyl)-diphenyl ether.
- 19 DBBP is dibenzoyl biphenyl.
- 20 BSO is benzoylated styrene oligomer comprising benzoylated styrene dimers,
- 21 trimers and pentamers.
- 22 BBP³ is tribenzoyl triphenylbenzene.

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- 1 DTBP is ditoluoyl biphenyl.
- 2 Good oxygen scavenging compositions consumed half of the available oxygen in less than 4 days.
- 4 Fair oxygen scavenging compositions consumed half of the available oxygen in 4-5 days.
- 6 Poor oxygen scavenging compositions consumed half of the available oxygen in greater than 6 days.
- 8 PI in extract is the amount of photoinitiator in ppb found in the extract (normalized to 10 g simulant/in² film).
- 10 DL is the detection limit defined as 3 times the instrument signal noise (normalized to 10 g simulant/in² film).
- 11 (normalized to 10 g simulant/in² film).

12

Table 1

| Run | Photo-initiator | Days to reach 0.5% Oxygen | Extraction Method | Triggered UV-254 | PI in Extract (ppb) | DL (ppb) |
|-----|-----------------|---------------------------|-------------------|------------------|---------------------|----------|
| 101 | ANTH | NA* | A | No | 663 | 7 |
| 102 | ANTH | 4-5 | A | 1 min. | 63 | 7 |
| 103 | ANTH | 4-5 | B | 1 min. | 85 | 26 |
| 201 | XAN | NA | A | No | 870 | 6 |
| 202 | XAN | > 6 | A | 1 min. | 269 | 6 |
| 203 | XAN | > 6 | B | 1 min. | 218 | 29 |
| 301 | BBP | NA | A | No | 834 | 6 |
| 302 | BBP | 3 | A | 1 min. | 358 | 6 |
| 303 | BBP | 3 | B | 1 min. | 357 | 26 |

| Run | Photo-initiator | Days to reach 0.5% Oxygen | Extraction Method | Triggered UV-254 | PI in Extract (ppb) | DL (ppb) |
|-----|------------------|---------------------------|-------------------|------------------|---------------------|----------|
| 401 | BBDE | NA | C | 1 min. | 1125 | 50 |
| 501 | DBBP | 3-4 | A | 1 min. | 404 | 8 |
| 502 | DBBP | 3-4 | B | 1 min. | 409 | 38 |
| 601 | BSO | 2-3 | A | 1 min. | ND** | 30 |
| 602 | BSO | 2-3 | B | 1 min. | 100 | 45 |
| 701 | BBP ³ | 2-3 | A | 1 min. | 23 | 5 |
| 702 | BBP ³ | 2-3 | B | 1 min. | ND | 20 |
| 801 | DTBP | 2-3 | A | 1 min. | ND | 7 |
| 802 | DTBP | 2-3 | B | 1 min. | ND | 30 |

1 *Not Available

2 **None detected

3 The Table above demonstrates the low leachability of and effective
 4 photoinitiation of the inventive photoinitiators. Runs 101-401 are submitted for
 5 comparative purposes. It is believed that removal of small molecular weight
 6 compounds from the BSO photoinitiator will further reduce its leachability.

7

Example 2

8 Three layer films were prepared as described in Example 1 with the exception of
 9 employing 1000 ppm by weight cobalt in the form of cobalt stearate as catalyst
 10 and benzoylated styrene oligomer and 4-benzoyl biphenyl individually as
 11 photoinitiators. The photoinitiators were also present at 1000 ppm by weight
 12 based on the oxygen scavenging composition.

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- 1 The results are graphically represented in Figure 3. The results demonstrate the
- 2 effectiveness of cobalt stearate and benzoylated styrene oligomer in providing
- 3 good oxygen scavenging in a relatively short time.

4

Example 3

5

Benzoylated Meta-Terphenyl

- 6 Meta-terphenyl 115 gram (0.5 mole) and benzoyl chloride 232 grams (1.65 mole)
- 7 were dissolved in 400 ml of nitrobenzene. The reactor temperature is
- 8 maintained at 40-50°C while 440 grams of aluminum chloride (3.3 mole) was
- 9 added in portions to control the exothermic reaction. The reaction mixture was
- 10 increased to 80°C for 4 hours and then poured into 3 L of 5% HCl solution. The
- 11 product was isolated by recrystallization from toluene and determined to be
- 12 di-benzoylated meta-terphenyl. The melting point was 205-208°C. The UV
- 13 spectra was similar to monomeric benzophenone. The molecular weight
- 14 determined by mass spectrometer was 438 g/mole.

1 WHAT IS CLAIMED IS:

2 1. An oxygen scavenging composition comprising an oxygen scavenging
3 material, a photoinitiator, and at least one catalyst effective in catalyzing
4 oxygen scavenging.

5 wherein the photoinitiator comprises at least one benzophenone derivative
6 containing at least two benzophenone moieties, and

7 wherein the photoinitiator is substantially non-extractable when the oxygen
8 scavenging composition is exposed to a food simulant

9 2. The oxygen scavenging composition according to Claim 1 wherein the
10 photoinitiator is represented by the following formula:

$$x_m(\gamma)$$

wherein each X is a bridging group selected from the group consisting of sulfur; oxygen; carbonyl; -SiR₂-, wherein each R is individually an alkyl group containing from 1 to 12 carbon atoms, an aryl group containing 6 to 12 carbon atoms, an alkoxy group containing from 1 to 12 carbon atoms; -NR'-, wherein R' is an alkyl group containing 1 to 12 carbon atoms, an aryl group containing 6 to 12 carbon atoms, or hydrogen; and an organic group containing from 1 to 50 carbon atoms:

19 wherein m is 0 to 11;

wherein Y is a substituted or unsubstituted benzophenone group, wherein each substituent, R", when present, is individually an alkyl, aryl, alkoxy,

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- 1 phenoxy, or alicyclic group containing from 1 to 24 carbon atoms, or a
- 2 halide; and
- 3 wherein n is 2-12.
- 4 3. The oxygen scavenging composition according to Claim 2 wherein the
- 5 combined molecular weight of X plus R" is at least 30 g/mole.
- 6 4. The oxygen scavenging composition according to Claim 1 wherein less
- 7 than 250 ppb of photoinitiator are extracted through a 0.5 mil polyethylene
- 8 film at room temperature from an oxygen scavenging composition
- 9 containing 1000 ppm by weight photoinitiator when exposed to 10 g fatty
- 10 food simulant per square inch of 1 mil film at room temperature after
- 11 10 days.
- 12 5. The oxygen scavenging composition according to Claim 4 wherein less
- 13 than 100 ppb of photoinitiator are extracted.
- 14 6. The oxygen scavenging composition according to Claim 5 wherein less
- 15 than 50 ppb of photoinitiator are extracted.
- 16 7. An oxygen scavenging composition comprising an oxygen scavenging
- 17 material, a photoinitiator, and at least one catalyst effective in catalyzing
- 18 oxygen scavenging,
- 19 wherein the photoinitiator comprises at least one benzophenone derivative
- 20 containing at least two benzophenone moieties, and

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- 1 wherein the photoinitiator, after being irradiated with UV light, is
- 2 substantially non-extractable when the oxygen scavenging composition is
- 3 exposed to a food simulant, and

- 4 wherein the oxygen scavenging composition has an induction period of
- 5 1 day or less.

- 6 8. The oxygen scavenging composition according to Claim 7 wherein less
- 7 than 250 ppb of photoinitiator are extracted from an oxygen scavenging
- 8 composition containing 1000 ppm by weight photoinitiator when exposed to
- 9 10 g fatty food simulant per square inch of 1 mil film at room temperature
- 10 after 10 days.

- 11 9. The oxygen scavenging composition according to Claim 8 wherein less
- 12 than 100 ppb of photoinitiator are extracted.

- 13 10. The oxygen scavenging composition according to Claim 9 wherein less
- 14 than 50 ppb of photoinitiator are extracted.

- 15 11. The oxygen scavenging composition according to Claim 8 which consumes
- 16 half of the available oxygen in a container containing 1 percent oxygen in
- 17 less than 4 days at 25°C.

- 18 12. The oxygen scavenging composition according to Claim 11 which
- 19 consumes half of the available oxygen in a container containing 1 percent
- 20 oxygen in less than 4 days at 4°C.

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- 1 13. The oxygen scavenging composition according to Claim 12 which exhibits
2 an oxygen scavenging capability of at least 0.1 cc O₂/gram of oxygen
3 scavenging composition/day at 25°C.
- 4 14. The oxygen scavenging composition according to Claim 13 which exhibits
5 an oxygen scavenging capability of at least about 0.5 cc O₂/gram of oxygen
6 scavenging composition/day at 25°C.
- 7 15. The oxygen scavenging composition according to Claim 14 which exhibits
8 an oxygen scavenging capability of at least about 1 cc O₂/gram of oxygen
9 scavenging composition/day at 25°C.
- 10 16. The oxygen scavenging composition according to Claim 15 which exhibits
11 an oxygen scavenging capability of at least about 1 cc O₂/gram of oxygen
12 scavenging composition/day at 4°C.
- 13 17. The oxygen scavenging composition of Claim 16 wherein the photoinitiator
14 has a molecular weight in the range of about 360 to about 5000.
- 15 18. The oxygen scavenging composition of Claim 7 wherein the photoinitiator
16 comprises tribenzoyl triphenylbenzene or substituted tribenzoyl
17 triphenylbenzene, wherein the substituents are alkyl, aryl, alkoxy, phenoxy,
18 or alicyclic groups containing from 1 to 24 carbon atoms or halides.
- 19 19. The oxygen scavenging composition of Claim 18 wherein the photoinitiator
20 comprises tribenzoyl triphenylbenzene or tritoluoyl triphenylbenzene.
- 21 20. The oxygen scavenging composition of Claim 7 wherein the photoinitiator
22 comprises benzoylated styrene oligomer or substituted benzoylated styrene

1 oligomer, wherein the substituents are alkyl, aryl, alkoxy, phenoxy, or
2 alicyclic groups containing from 1 to 24 carbon atoms or halides.

3 21. The oxygen scavenging composition of Claim 20 wherein the photoinitiator
4 comprises di-benzoylated styrene trimer, tri-benzoylated styrene pentamer,
5 - tetra-benzoylated styrene pentamer or di-benzoylated styrene dimer.

6 22. The oxygen scavenging composition of Claim 7 wherein the photoinitiator
7 comprises substituted dibenzoyl biphenyl, wherein the substituents are
8 alkyl, aryl, alkoxy, phenoxy, or alicyclic groups containing from 1 to
9 24 carbon atoms or halides.

10 23. The oxygen scavenging composition of Claim 22 wherein the photoinitiator
11 comprises ditoluoyl biphenyl.

12 24. The oxygen scavenging composition of Claim 7 wherein the photoinitiator
13 comprises benzoylated terphenyl or substituted benzoylated terphenyl,
14 wherein the substituents are alkyl, aryl, alkoxy, phenoxy, or alicyclic groups
15 containing from 1 to 24 carbon atoms or halides.

16 25. The oxygen scavenging composition of Claim 24 wherein the photoinitiator
17 comprises dibenzoylated meta-terphenyl.

18 26. The oxygen scavenging composition of Claim 7 wherein the photoinitiator is
19 present in an amount in the range of from about 0.001 weight percent to
20 about 10 weight percent based on the total weight of the oxygen
21 scavenging composition.

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- 1 27. The oxygen scavenging composition of Claim 26 wherein the photoinitiator
2 is present in an amount in the range of from about 0.005 weight percent to
3 about 5 weight percent based on the total weight of the oxygen scavenging
4 composition.
- 5 28. The oxygen scavenging composition of Claim 7 wherein the oxygen
6 scavenging material is an organic compound.
- 7 29. The oxygen scavenging composition of Claim 28 wherein the oxygen
8 scavenging material is an ethylenically unsaturated organic compound.
- 9 30. The oxygen scavenging composition of Claim 28 wherein the oxygen
10 scavenging material is an organic polymer.
- 11 31. The oxygen scavenging composition of Claim 30 wherein the oxygen
12 scavenging material is polybutadiene, polyisoprene, styrene-butadiene
13 block copolymers, acrylates which are prepared by transesterification of
14 poly(ethylene-methyl acrylate), or a polyterpene.
- 15 32. The oxygen scavenging composition of Claim 31 wherein the oxygen
16 scavenging material is poly(alpha-pinene), poly(dipentene),
17 poly(beta-pinene), or poly(limonene).
- 18 33. The oxygen scavenging composition of Claim 31 wherein the oxygen
19 scavenging material is styrene-butadiene-styrene block copolymer.
- 20 34. The oxygen scavenging composition of Claim 7 wherein the oxygen
21 scavenging material is present in an amount in the range of from about

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- 1 1 weight percent to about 99 weight percent based on the total oxygen
- 2 scavenging composition.
- 3 35. The oxygen scavenging composition of Claim 34 wherein the oxygen
- 4 scavenging material is present in an amount in the range of from about
- 5 5 weight percent to about 95 weight percent based on the total oxygen
- 6 scavenging composition.
- 7 36. The oxygen scavenging composition of Claim 35 wherein the oxygen
- 8 scavenging material is present in an amount in the range of from 10 weight
- 9 percent to 90 weight percent based on the total oxygen scavenging
- 10 composition.
- 11 37. The oxygen scavenging composition of Claim 7 wherein the catalyst is a
- 12 transition metal salt.
- 13 38. The oxygen scavenging composition according to Claim 37 wherein the
- 14 catalyst is a cobalt salt.
- 15 39. The oxygen scavenging composition according to Claim 38 wherein the
- 16 catalyst is cobalt oleate, cobalt linoleate, cobalt neodecanoate, cobalt
- 17 stearate, or cobalt caprylate.
- 18 40. The oxygen scavenging composition according to Claim 39 wherein the
- 19 catalyst is cobalt oleate.
- 20 41. The oxygen scavenging composition according to Claim 39 wherein the
- 21 catalyst is cobalt stearate and the photoinitiator is benzoylated styrene
- 22 oligomer or benzoylated m-terphenyl.

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- 1 42. The oxygen scavenging composition according to Claim 7 wherein the
2 catalyst is present in an amount in the range of from about 10 ppm to about
3 10,000 ppm transition metal ion based on the total weight of the oxygen
4 scavenging composition.
- 5 43. The oxygen scavenging composition according to Claim 7 which is
6 activated with radiation having a wave length in the range of from about
7 200 to about 400 nm.
- 8 44. The oxygen scavenging composition according to Claim 7 wherein the
9 oxygen scavenging material comprises a first phase and the catalyst
10 comprises a second phase, wherein the second phase is in sufficiently
11 close proximity to the first phase to catalyze an oxygen scavenging
12 reaction.
- 13 45. The oxygen scavenging composition according to Claim 44 wherein the first
14 phase forms a first layer and the second phase forms a second layer.
- 15 46. The oxygen scavenging composition according to Claim 45 wherein the
16 second layer is in contact with the first layer.
- 17 47. The oxygen scavenging composition according to Claim 46 further
18 comprising an oxygen barrier layer, a selective barrier layer, or a heat seal
19 layer.
- 20 48. A film comprising the oxygen scavenging composition of Claim 7.
- 21 49. A film comprising the oxygen scavenging composition of Claim 45.

- 1 50. An article comprising the oxygen scavenging composition of Claim 7.
- 2 51. The article of Claim 50 wherein the article is a package.
- 3 52. The article of Claim 51 wherein the article is a package containing a food or
4 - beverage product, cosmetic, chemical, electronic device, pesticide or
5 pharmaceutical.
- 6 53. The article of Claim 50 wherein the article is a patch, bottle cap insert, or
7 molded or thermoformed shape.
- 8 54. The article of Claim 53 wherein the molded or thermoformed shape is a
9 bottle or tray.
- 10 55. A method for scavenging oxygen within a package comprising sealing an
11 oxygen-sensitive product in the package of Claim 47.
- 12 56. The method of Claim 55 wherein the package is activated with at least
13 0.1 J/cm² UV radiation from 200 to 400 nm.
- 14 57. A method for preparing an oxygen scavenging composition comprising melt
15 blending an oxygen scavenging material, a photoinitiator and at least one
16 catalyst effective in catalyzing oxygen scavenging,
17 wherein the photoinitiator comprises a benzophenone derivative containing
18 at least two benzophenone moieties, and
19 wherein the photoinitiator is substantially non-extractable when the oxygen
20 scavenging composition is exposed to a food simulant.

- 1 58. A photoinitiator which is tribenzoyl triphenylbenzene or a substituted
2 tribenzoyl triphenylbenzene, wherein the substituents are alkyl, aryl, alkoxy,
3 phenoxy, or alicyclic groups containing from 1 to 24 carbon atoms or halides.
- 4 59. A method for preparing the photoinitiator of Claim 58 comprising reacting a
5 substituted or unsubstituted benzoyl halide with a substituted or
6 unsubstituted triphenylbenzene.
- 7 60. A photoinitiator which is benzoylated styrene oligomer or a substituted
8 benzoylated styrene oligomer containing from 2 to 12 repeating styrenic
9 groups, wherein the substituents are alkyl, aryl, alkoxy, phenoxy, or alicyclic
10 groups containing from 1 to 24 carbon atoms or halides.
- 11 61. The photoinitiator according to Claim 60 wherein the benzoylated styrene
12 oligomer comprises di-benzoylated styrene trimer, tri-benzoylated styrene
13 pentamer, tetra-benzoylated styrene pentamer, and di-benzoylated styrene
14 dimer.
- 15 62. A method for preparing the photoinitiator of Claim 61 comprising reacting
16 substituted or unsubstituted styrene trimers with substituted or
17 unsubstituted benzoyl halide.
- 18 63. A photoinitiator which is benzoylated meta-terphenyl or a substituted
19 benzoylated meta-terphenyl.
- 20 64. A method for preparing the photoinitiator of Claim 63 comprising reacting
21 meta-terphenyl or substituted meta-terphenyl with benzoyl halide or
22 substituted benzoyl halide.

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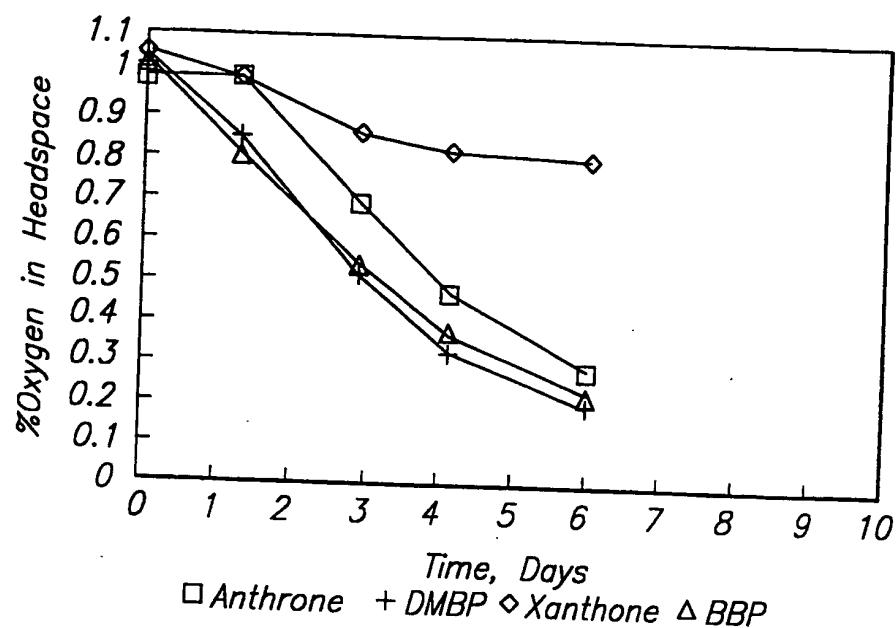


FIG. 1

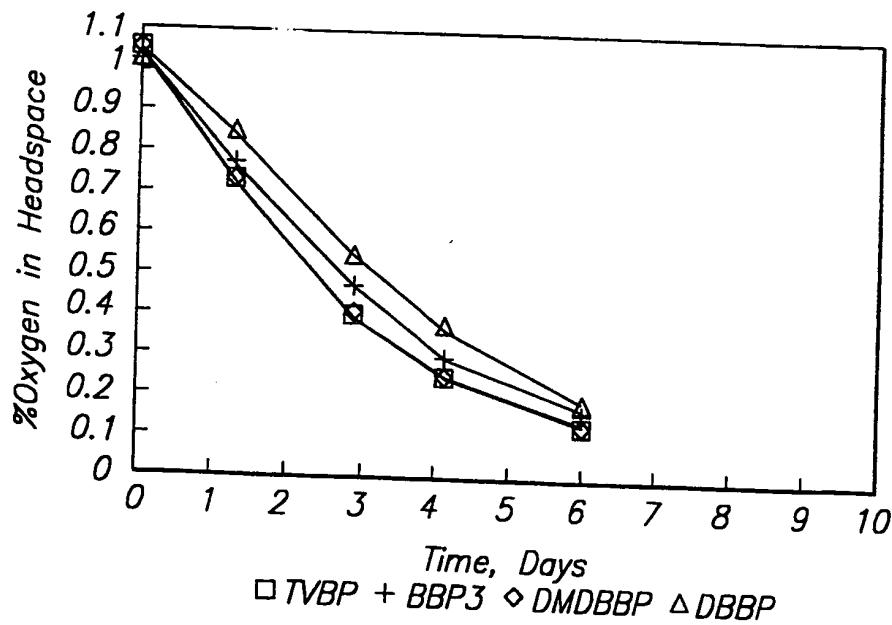


FIG. 2

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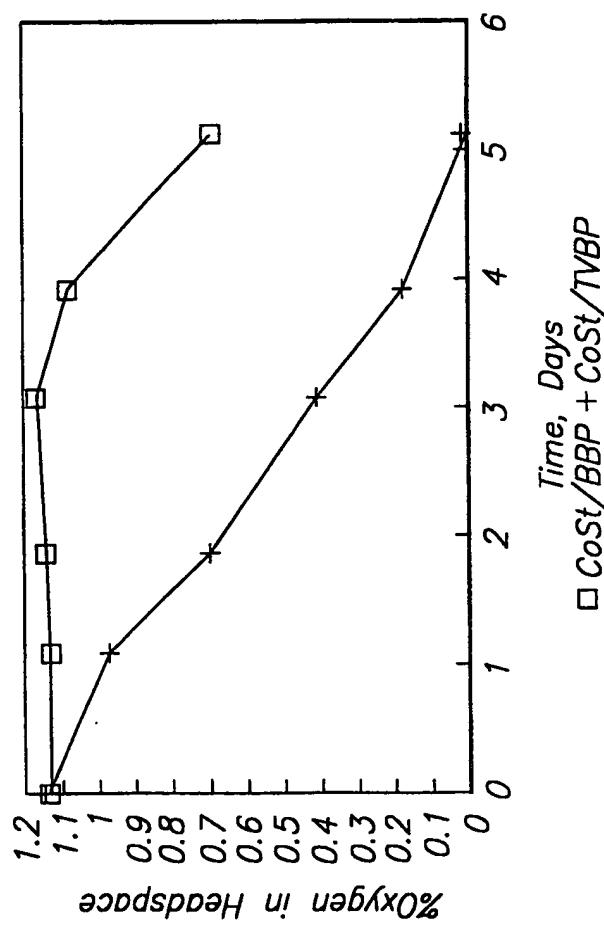


FIG. 3

INTERNATIONAL SEARCH REPORT

| | |
|------------------------------|-----------------|
| International Application No | PCT/US 98/07734 |
|------------------------------|-----------------|

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|-------------------------------------|-----------|------------|------------|-----------|-----------|
| A. CLASSIFICATION OF SUBJECT MATTER | | | | | |
| IPC 6 | C09K15/06 | A23L3/3436 | C07C49/786 | C07C45/46 | B32B27/18 |
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According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

| |
|---|
| Minimum documentation searched (classification system followed by classification symbols) |
| IPC 6 C09K A23L C07C B32B B65D C08K |

| |
|---|
| Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched |
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| Electronic data base consulted during the international search (name of data base and, where practical, search terms used) |
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C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Further documents are listed in the continuation of box C.

Patent family members are listed in annex.

* Special categories or cited documents :

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Date of the actual completion of the international search

15 July 1998

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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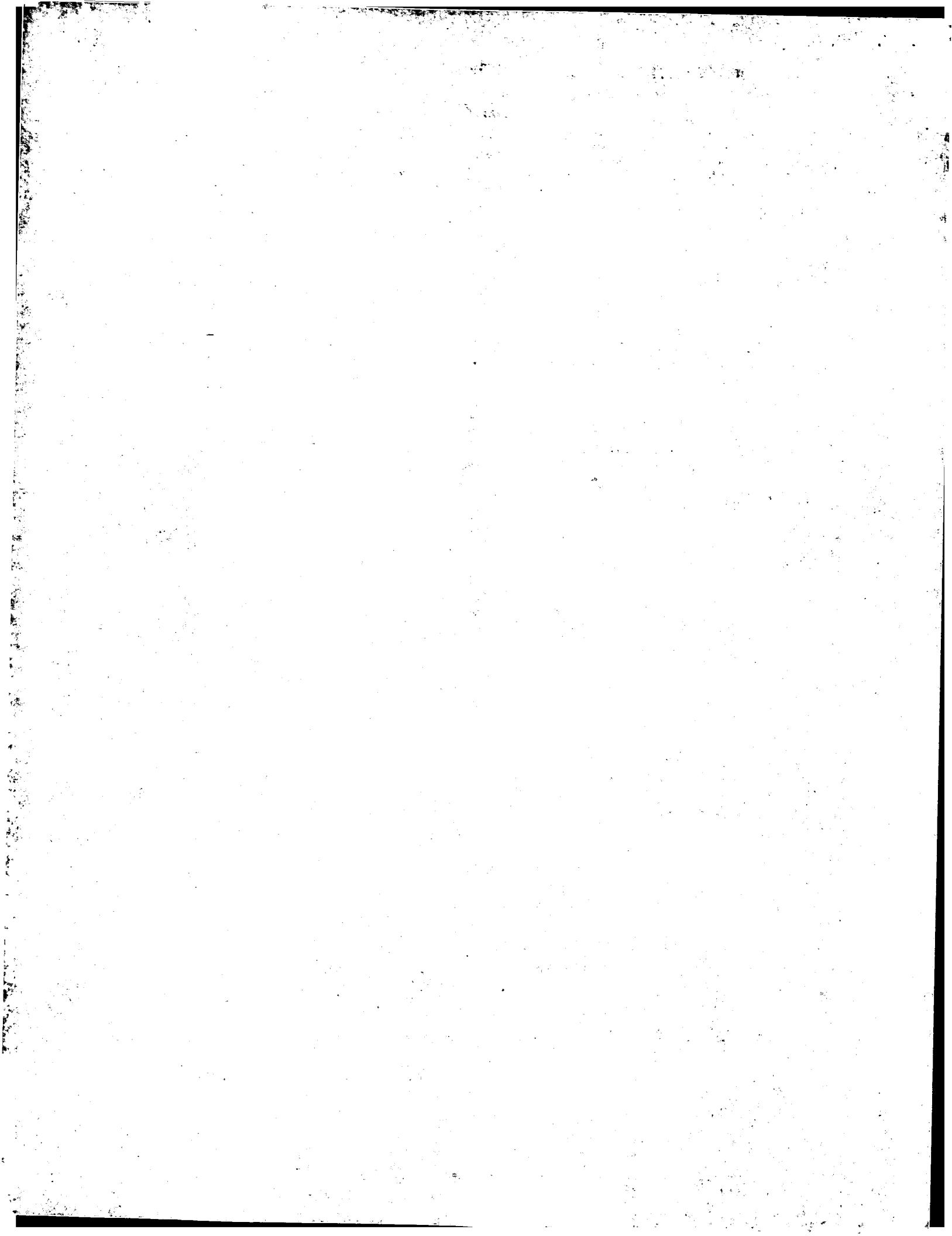
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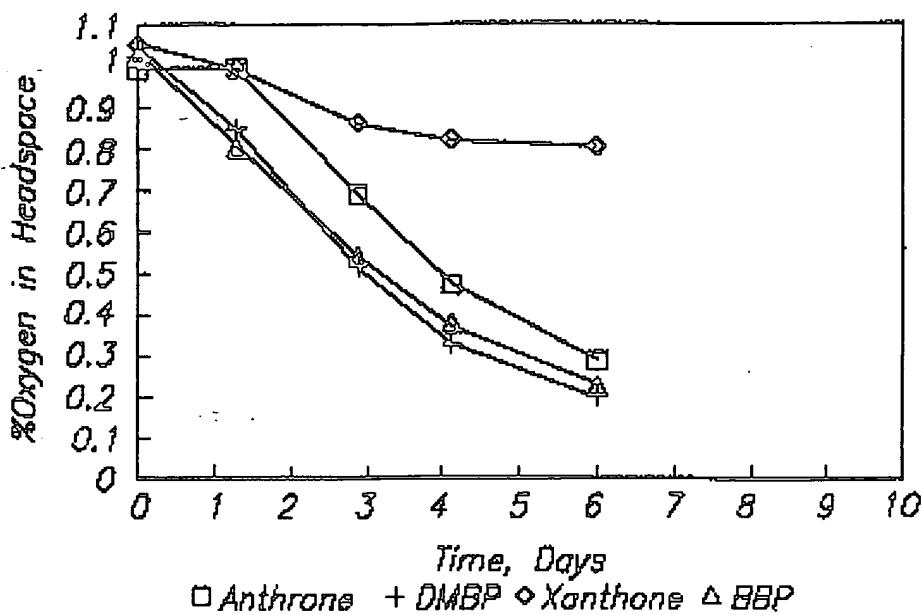


FIG. 1

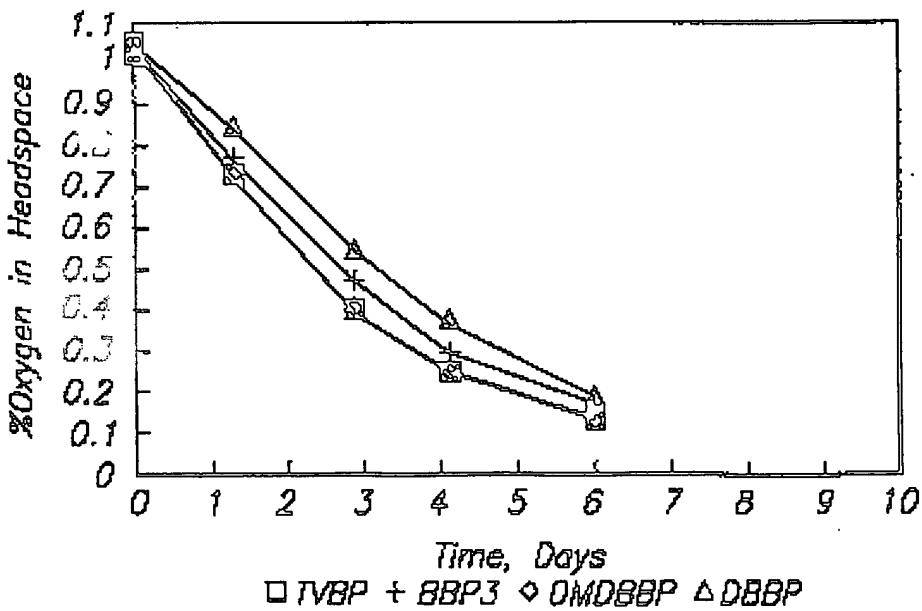


FIG. 2

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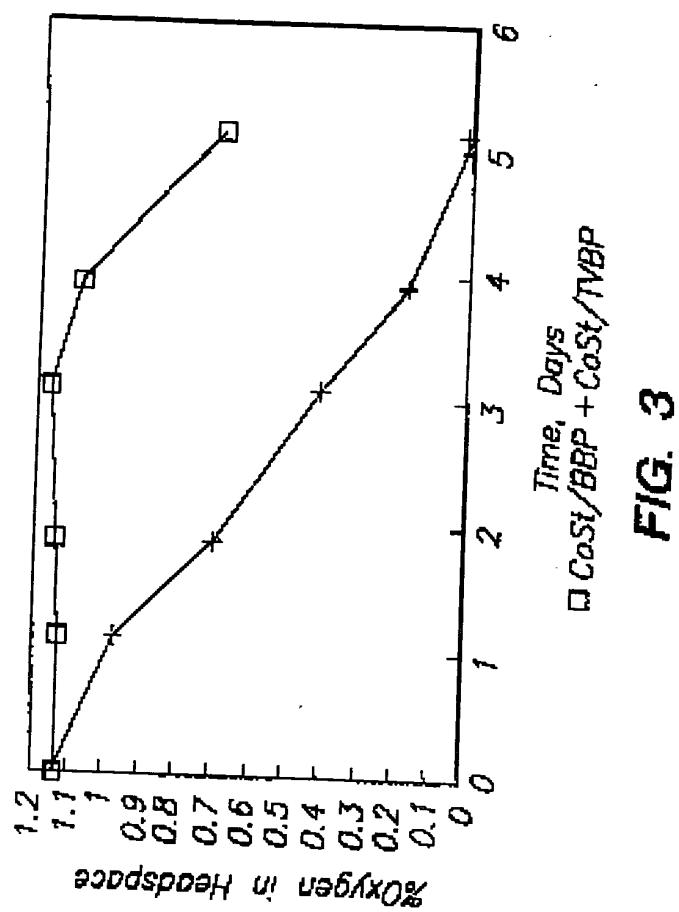


FIG. 3